Climate Change Summary, Canyon de Chelly National Monument, Arizona

Patrick Gonzalez

Natural Resource Stewardship and Science, U.S. National Park Service, Washington, DC

January 21, 2015

Climate Trends for the Area within Park Boundaries

- Average annual temperature has increased at a statistically significant rate since 1950 (Table 1, Figure 1). Spring (March-May) temperature has increased at the greatest rate, a statistically significant 2.6 ± 0.8°C (4.7 ± 1.4°F.) per century.
- Average total precipitation has increased since 1950, but the rate has not been statistically significant (Table 1, Figure 2. Precipitation has increased most in winter (December-February), but decreased in summer (June-August).
- If the world does not reduce emissions from power plants, cars, and deforestation by 40-70%, models project substantial warming and changes in precipitation (Table 1, Figure 3).
- The greatest warming could occur in autumn (September-November).
- Models projections of precipitation do not agree, with many projecting increases and many projecting decreases (Figure 3).
- Projections under the highest emissions scenario project 20-25 more days per year with a maximum temperature >35°C (95°F.) and an increase in 20-year storms (a storm with more precipitation than any other storm in 20 years) to once every 6-10 years (Walsh et al. 2014).

Historical Impacts in the Region

- Drought and bark beetle infestations in the early 2000s caused extensive dieback of piñon pine in Arizona forests (Breshears et al. 2005). This and numerous other cases of tree dieback around the world are consistent with climate change (Allen et al. 2010).
- Across the western U.S., including forest areas in Arizona, climate controlled the extent of burned area from 1916 to 2003 (Littell et al. 2009).
- Analyses of Audubon Christmas Bird Count data across the United States, including counts in Arizona, detected a northward shift of winter ranges of a set of 254 bird species at an average rate of 0.5 ± 0.3 km per year from 1975 to 2004, attributable to human climate change and not other factors (La Sorte and Thompson 2007).

Future Vulnerabilities in the Region

- Under all emissions scenarios, reduced snowfall, changing patterns of rainfall, and increased temperature could reduce the flow of springs, streams, and rivers (Garfin et al. 2014).
- Under high emissions, wildfire frequencies could increase up to 25% by 2100 (Moritz et al. 2012).
- Under continued warming, forest drought stress could continue to cause substantial tree dieback and possible conversion of some forest to grassland (Williams et al. 2013).
- Under a high emissions scenario, climate change could increase densities of the invasive species tamarisk (*Tamarix spp.*) (Bradley et al. 2009) and Russian olive (*Elaeagnus angustifolia*) (Jarnevich and Reynolds 2010).

Table 1. Historical rates of change per century and projected future changes in annual average temperature and annual total precipitation (data Daly et al. 2008, IPCC 2013; analysis Wang et al. in preparation). The table gives the historical rate of change per century calculated from data for the period 1950-2010. Because a rate of change per century is given, the absolute change for the 1950-2010 period will be approximately 60% of that rate. The table gives central values for the park as a whole. Figures 1-3 show the uncertainties.

	1950-2010	2000-2050	2000-2100
Historical			
temperature	+1.2ºC/century (2.2ºF./century)		
precipitation	+15%/century		
Projected (compared to 1971-2000)			
Low emissions (IPCC RCP 4.5)			
temperature		+2.3ºC (+4.1ºF.)	+2.9ºC (+5.2ºF.)
precipitation		+1	+3%
High emissions (IPCC RCP 6.0)			
temperature		+2ºC (+3.6ºF.)	+3.4ºC (+6.1ºF.)
precipitation		~0	+1
Highest emissions (IPCC RCP 8.5)			
temperature		+2.9ºC (+5.2ºF.)	+5.2ºC (+9.4ºF.)
precipitation		+2%	+2%

Figure 1. Historical annual average temperature for the area within park boundaries. Note that the U.S. weather station network was more stable for the period starting 1950 than for the period starting 1895. (Data: National Oceanic and Atmospheric Administration, Daly et al. 2008. Analysis: Wang et al. in preparation, University of Wisconsin and U.S. National Park Service).

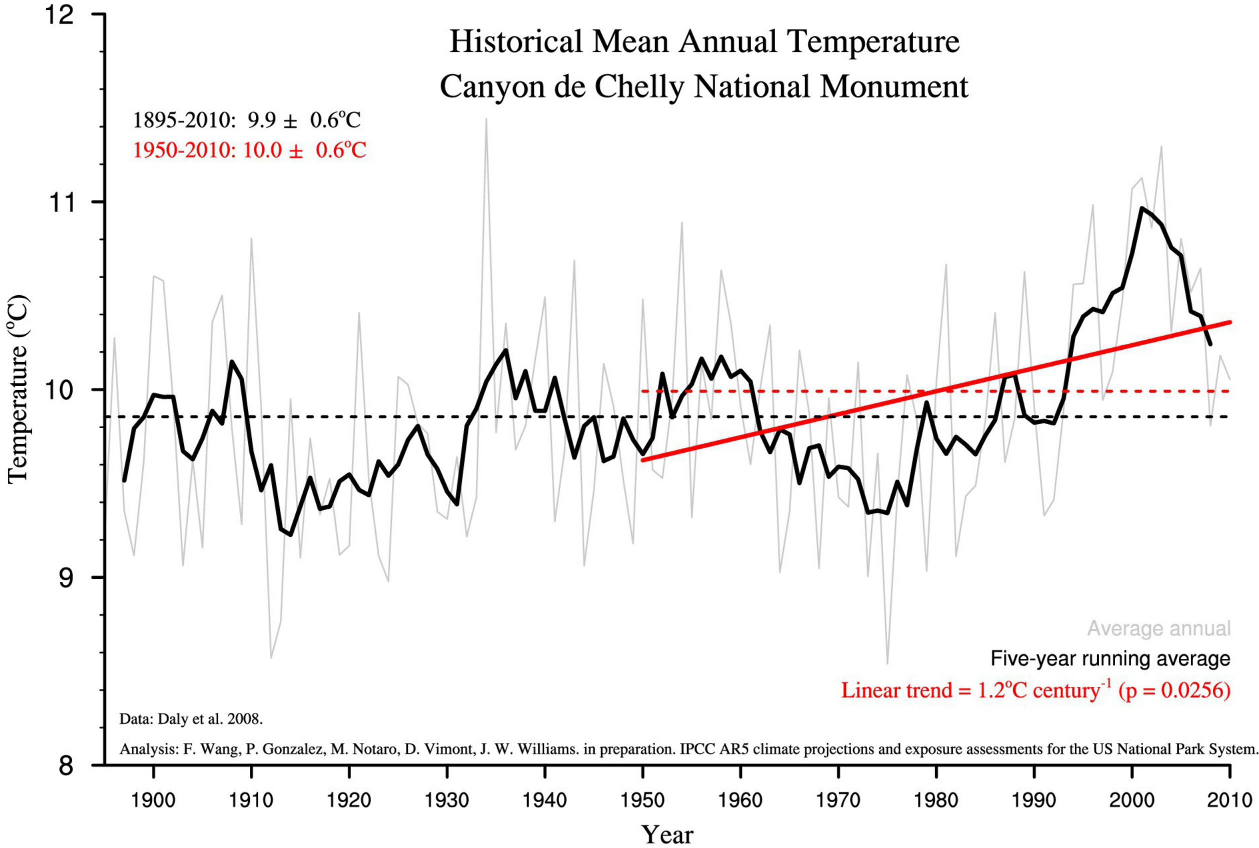


Figure 2. Historical annual total precipitation for the area within park boundaries. Note that the U.S. weather station network was more stable for the period starting 1950 than for the period starting 1895. (Data: National Oceanic and Atmospheric Administration, Daly et al. 2008. Analysis: Wang et al. in preparation, University of Wisconsin and U.S. National Park Service).

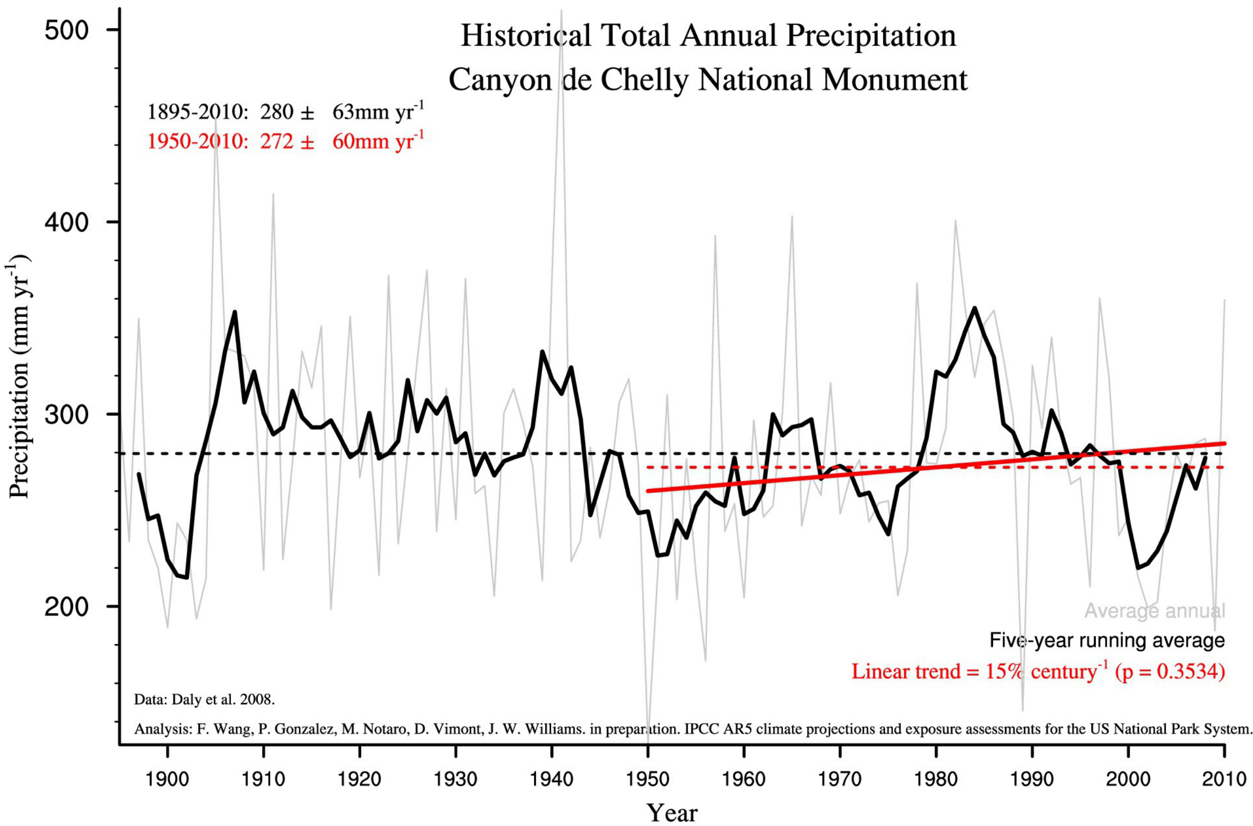
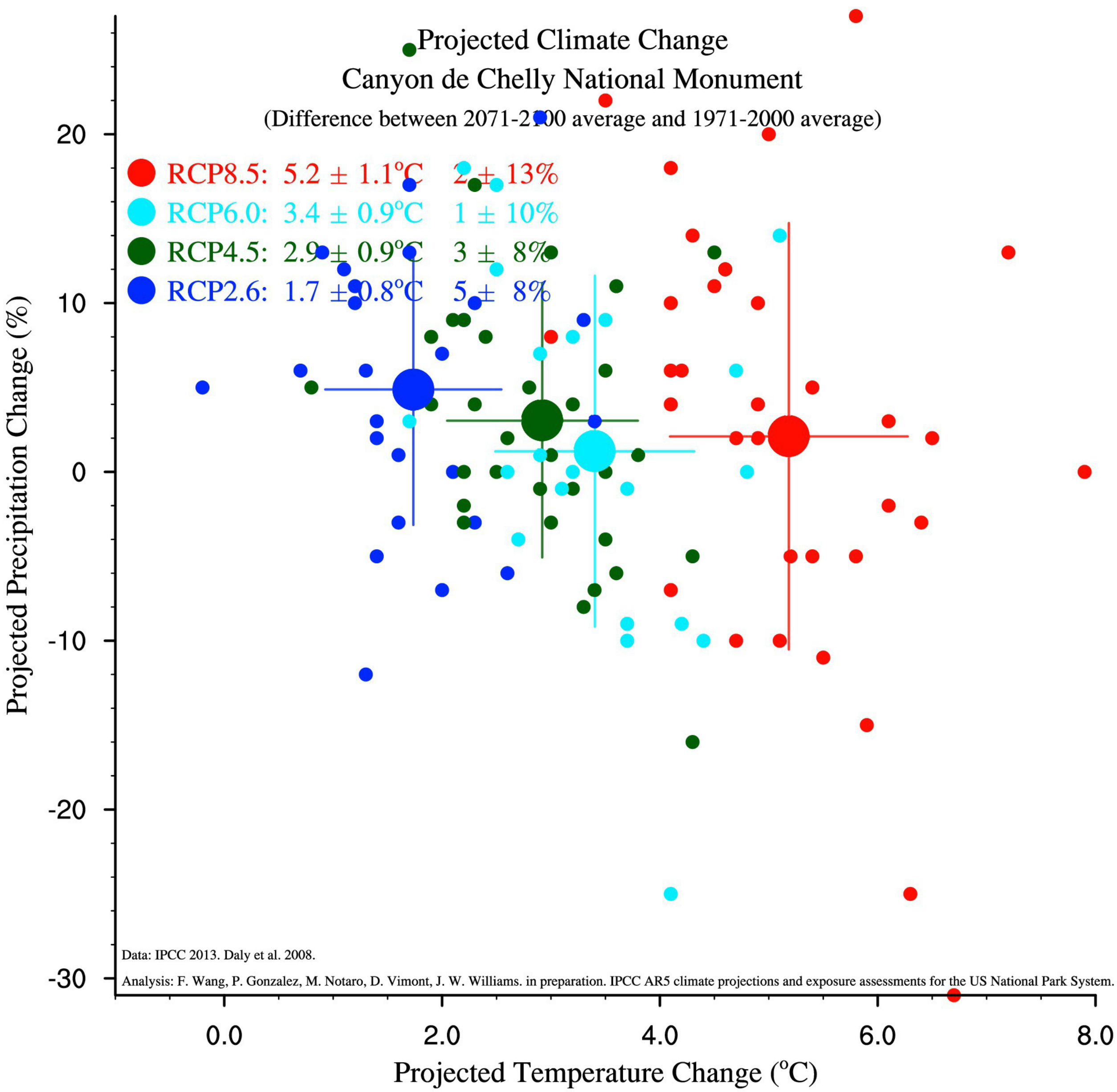


Figure 3. Projections of future climate for the area within park boundaries. Each small dot is the output of a single climate model. The large color dots are the average values for the four IPCC emissions scenarios. The lines are the standard deviations of each average value. (Data: IPCC 2013, Daly et al. 2008; Analysis: Wang et al. in preparation, University of Wisconsin and U.S. National Park Service).



References

Allen, C.D., A.K. Macalady, H. Chenchouni, D. Bachelet, N. McDowell, M. Vennetier, T. Kitzberger, A. Rigling, D.D. Breshears, E.H. Hogg, P. Gonzalez, R. Fensham, Z. Zhang, J. Castro, N. Demidova, J.H. Lim, G. Allard, S.W. Running, A. Semerci, and N. Cobb. 2010. A global overview of drought and heat-induced tree mortality reveals emerging climate change risks for forests. Forest Ecology and Management 259: 660-684.

Bradley, B.A., M. Oppenheimer, and D.S. Wilcove. 2009. Climate change and plant invasions: restoration opportunities ahead? Global Change Biology 15: 1511-1521.

Breshears, D.D., N.S. Cobb, P.M. Rich, K.P. Price, C.D. Allen, R.G. Balice, W.H. Romme, J.H. Kastens, M.L. Floyd, J. Belnap, J.J. Anderson, O.B. Myers, and C.W. Meyer. 2005. Regional vegetation die-off in response to global-change-type drought. Proceedings of the National Academy of Sciences of the USA 102: 15 144-15 148.

Daly, C., M. Halbleib, J.I. Smith, W.P. Gibson, M.K. Doggett, G.H. Taylor, J. Curtis, and P.P. Pasteris. 2008. Physiographically sensitive mapping of climatological temperature and precipitation across the conterminous United States. International Journal of Climatology 28: 2031-2064.

Garfin, G., G. Franco, H. Blanco, A. Comrie, P. Gonzalez, T. Piechota, R. Smyth, and R. Waskom. 2014. Southwest. In Melillo, J.M., T.C. Richmond, and G.W. Yohe (Eds.) 2014. Climate Change Impacts in the United States: The Third National Climate Assessment. U.S. Global Change Research Program, Washington, DC.

Intergovernmental Panel on Climate Change (IPCC). 2013. Climate Change 2013: The Physical Science Basis. Cambridge University Press, Cambridge, UK.

Jarnevich, C.S. and L.V. Reynolds. 2010. Challenges of predicting the potential distribution of a slow-spreading invader: A habitat suitability map for an invasive riparian tree. Biological Invasions 13: 153-163.

La Sorte, F.A. and F.R. Thompson. 2007. Poleward shifts in winter ranges of North American birds. Ecology 88: 1803-1812.

Littell, J.S., D. McKenzie, D.L. Peterson, and A.L. Westerling. 2009. Climate and wildfire area burned in western U.S. ecoprovinces, 1916–2003. Ecological Applications 19: 1003-1021.

Moritz, M.A., M.A. Parisien, E. Batllori, M.A. Krawchuk, J. Van Dorn, D.J. Ganz, and K. Hayhoe. 2012. Climate change and disruptions to global fire activity. Ecosphere 3: art49. doi:10.1890/ES11-00345.1.

Walsh, J., D. Wuebbles, K. Hayhoe, J. Kossin, K. Kunkel, G. Stephens, P. Thorne, R. Vose, M.

Wehner, and J. Willis. 2014. Our changing climate. In Melillo, J.M., T.C. Richmond, and G. W. Yohe (Eds.) Climate Change Impacts in the United States: The Third National Climate Assessment. U.S. Global Change Research Program, Washington, DC.

Wang, F., P. Gonzalez, M. Notaro, D. Vimont, and J.W. Williams. in preparation. Significant historical and projected climate change in U.S. national parks.

Williams, A.P., C.D. Allen, A.K. Macalady, D. Griffin, C.A. Woodhouse, D.M. Meko, T.W. Swetnam, S.A. Rauscher, R. Seager, H.D. Grissino-Mayer, J.S. Dean, E.R. Cook, C. Gangodagamage, M. Cai, and N.G. McDowell. 2013. Temperature as a potent driver of regional forest drought stress and tree mortality. Nature Climate Change 3: 292-297.